Missouri Department of Conservation

FOREST RESEARCH REPORT No. 5

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David Gwaze[1], Doyle Henken[2] and Mark Johanson[3]

[1]Missouri Department of Conservation
1110 S. College Avenue
Columbia, MO 65201

[2]USDA Forest Service
Mark Twain National Forest
108 S. Sam Houston Blvd.
Houston, MO 65483

[3]Missouri Department of Conservation
Route 2 Box 198
Ellington, MO 63638

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ABSTRACT

Restoration of shortleaf pine (*Pinus echinata* Mill.) is a high priority for Missouri's resource managers. Shortleaf pine once occupied 6.6 million acres and now is found on only 397,100 acres. Extensive logging from 1880 to 1920, frequent wildfires and overgrazing are collectively suggested as the primary causes of shortleaf population decline. Restoration efforts have been motivated by the fact that shortleaf pine is a major component of Missouri's biodiversity and natural heritage, and it provides habitat and food for a diverse array of wildlife. This review examines the use of direct seeding for shortleaf pine restoration. It suggests that direct seeding is a potentially viable method for restoring shortleaf pine in Missouri. The keys to successful restoration of shortleaf pine using direct seeding involve good site preparation, sowing on competition-free sites, using quality seed, proper timing of sowing, protection of seed from birds and rodents, adequate moisture during germination and establishment and sufficient light on the site.

Keywords: Direct seeding, restoration, *Pinus echinata*

INTRODUCTION

There is considerable interest in restoring shortleaf pine (*Pinus echinata* Mill.) on both public and private lands in Missouri. Shortleaf pine is the only native pine species in Missouri and its range has declined drastically since European settlement. Shortleaf pine once occupied 6.6 million acres and now occupies only 397,100 acres of its former range (Essex and Spencer 1976). Extensive logging from 1880 to 1920, frequent wildfires and overgrazing are suggested as primary factors associated with the reduced population of shortleaf pine in Missouri (Brinkman and Smith 1968, Cunningham and Hauser 1989). Due to the ecological, economical, cultural and scientific importance of shortleaf pine in Missouri, both natural and artificial regeneration of shortleaf pine are being actively promoted to avoid continued decline of the shortleaf pine ecosystem and restore it to sites where it was originally found.

Direct seeding is a potentially viable method for restoring shortleaf pine, but it has not been extensively used in Missouri. An estimated 20,000 acres have been direct seeded with shortleaf pine in Missouri, of which about half are on the Mark Twain National Forest. About one million acres have been direct seeded with pine in the southern United States (Derr and Mann 1971). The main attraction of direct seeded over planted seedlings is reduced initial cost (Williston and Balmer 1983). In Missouri the total cost of direct seeding is one-third to one-half that of planting seedlings (Seidel and Rogers 1965). Present estimates of the initial costs indicate that those for direct seeding are less than one-half of those for planted seedlings in Missouri. This is due primarily to the direct seeding labor costs that are only one-third as much as planting. Also, seed and site preparation costs are lower.

Direct seeded shortleaf pine has the added advantage of developing natural root systems on site, thus reducing risk for root injuries and distortion that are sometimes associated with planted seedlings (Williston and Balmer 1983). As much as 30 percent of planted shortleaf pine in Arkansas lacked a taproot compared to only 15 percent of seeded seedlings (Harrington et al. 1986). However, with proper planting root problems associated with planted seedlings can be reduced. Another advantage of direct seeding is that transplant shock is avoided. Also, root systems that are allowed to develop naturally are likely to enable seedlings to be more tolerant to stress and wind damage.

Direct seeding can be done over a longer time period: unstratified seed is sown in fall and stratified seed is sown late winter or early spring. Direct seeding has particular advantages in regenerating shortleaf pine on sites with poor access, difficult terrain or rocky shallow soils and where planting is difficult and expensive (Williston and Balmer 1983). Direct seeding is a good alternative method to regenerate shortleaf pine in areas where there are no seed trees (Phares and Liming 1961). When harvesting does not coincide with a good seed crop or where few seed trees exist, direct seeding can be used to supplement natural regeneration. A good seed crop occurs once every 5 to 7 years

in shortleaf pine (Brinkman and Rogers 1967).

Direct seeding is a more precise method than natural regeneration for obtaining stocking goals. Direct seeding, as does planting, gives an opportunity to alter the genetic composition of the new forest to achieve certain management objectives (e.g. better production, greater genetic diversity, etc.). This is a particularly important factor in the Missouri Ozarks where most of the forests have been high graded. Thus, direct seeding offers a flexible and efficient way to restore shortleaf pine in Missouri.

Although direct seeding is an appealing method to regenerate shortleaf pine, it has some limitations. The greatest limitation is probably the effect of dry weather during the first year after germination. Dry conditions during seedling establishment may result in low survival rates. Other disadvantages include reduced control over spacing and stocking, costly pre-commercial thinning, predation by birds and small mammals and seed lost to heavy rain (Williston and Balmer 1983). Direct seeding requires a large amount of seed that may be difficult to collect in natural stands or may not be available. In general, direct seeded trees do not effectively compete with other vegetation and hence may have lower survival and slower growth compared to planted seedlings.

This review presents published and unpublished research on direct seeding of shortleaf pine in the United States, with particular emphasis on Missouri. The review highlights some significant lessons learned and suggests some research and information gaps. The review will not only be useful as a reference for researchers working on artificial regeneration of shortleaf pine, but also for resource managers and private landowners interested in restoring shortleaf pine in Missouri.

Proper seedbed conditions are critical for germination and survival of direct seeded shortleaf pine. Shortleaf pine direct seeding is most successful on exposed mineral soil with sufficient light (Billings 1936, Boggs and Wittwer 1993, Bringman and Smith 1968, Derr and Mann 1971, Lawson 1990). Therefore for successful germination and establishment, heavy hardwood leaf litter, forbs, woody vegetation and grass should be eliminated or reduced. In loblolly-shortleaf pine stands in Arkansas, seedlings in uneven-aged stands had limited establishment where litter depth exceeding three inches (Figure 1, Grano 1949). In the Ozark Highlands only 12 percent of the viable seed sown on unprepared sites germinated compared to 34 percent germination on prepared sites (Liming 1945). Under controlled conditions, seed in contact with moist soil germinated rapidly, while germination of seed in contact with decomposing litter was restricted (Pomeroy 1949). Damping-off associated with high organic matter increases seedling mortality (Pomeroy 1949).

Fire or mechanical disturbances are effective site preparation methods because they remove the dense leaf litter and vegetation, and expose seed to the mineral soil. Shortleaf pine establishment is inversely related to years since burning (Ferguson 1958). In Oklahoma at least three times as many seedlings emerged on burned sites than on unburned sites (Figure 2, Boggs and Wittwer 1993). In the Missouri Ozarks cultivation after removal of litter was a superior site preparation method compared to burning or raking (Liming 1945). Prescribed burning provided little additional seedbed benefit in sites disturbed by logging in Arkansas (Yocom and Lawson 1977). In general, fire is likely to create more uniform seedbed conditions than mechanical or hand disturbances.

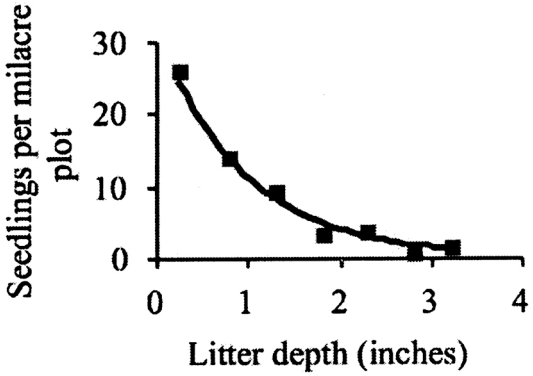

Figure 1. Relationship between average litter depth and establishment of pine seedlings in an uneven aged loblolly-shortleaf pine stands in Arkansas (adapted from Grano 1949).

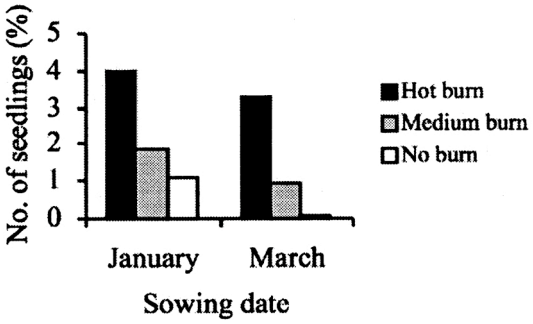

Figure 2. Number of established seedlings as a percentage of seeds sown (Boggs and Wittwer 1993). For January sowing seed was not stratified, but was stratified for March sowing.

Establishment is best if a small amount of overstory shade is present to prevent seedling desiccation, particularly

on exposed sites (Lawson 1979). However, shortleaf pine will need to be released from either competing understory vegetation or overtopping trees in order to survive and grow well. Reducing canopy closure by 75 percent improved survival of directly seeded plants from 16 percent to 60 percent and height growth from 6.2 inches to 33 inches after five growing seasons (Liming 1945). Generally, newly established shortleaf pine seedlings are moderately shade tolerant but become less tolerant with age.

SEED OUALITY AND HANDLING

Quality of seed prior to sowing in the field affects survival and growth of directly seeded shortleaf pine. For example, selection of appropriate seed source is critical for any artificial regeneration program. Poor choice of seed source can reduce survival and growth of trees and sometimes causes outright failures. To maximize growth and survival, seeds should come from an area having a minimum temperature within 5^0F of the planting site's minimum temperature (Schimdtling 2001).

Growth and survival may be improved by using orchard seed or certified seed. Seed from natural stands should be collected from superior trees to increase the chance of vigorous progeny. The percentage of sound seed is reported to be highest in years of high seed production (Pomeroy and Kostian 1949). Good seed crops in shortleaf pine occur once every 5 to 7 years (Brinkman and Rogers 1967). Hence, timing of seed collections is important. Seed quality also influences sowing rates. For example, when using high genetic quality seed from a seed orchard only a few seeds are required for spot sowing, reducing pre-commercial thinning costs.

Proper seed storage will ensure good seed germination. To prevent rapid loss of seed viability, seed moisture should be reduced to 5 percent and seed should be stored in airtight containers at 20^0F (Mugford 1984). Prior to storage, seedlots should be 95 percent pure and have a germination capacity of 80 percent or more. With proper seed storage high seed viability can be maintained for as long as 35 years (Wakeley and Barnett 1968).

Sound seeds of known origin or high genetic quality should be stratified. Shortleaf pine seed is dormant and will not germinate unless it undergoes stratification. Stratification of shortleaf pine seed can be achieved naturally by sowing in fall. It can also be achieved by soaking seed in water for 24 hours, placing wet seed in polythene bags and storing in cold storage at temperatures of 32 to 36^0F for 30 days (Mugford 1984).

Seed predation by birds and rodents is cited as a major problem when direct seeding shortleaf pine in Missouri (Mugford 1984). Predation can be reduced by treating seeds with repellents such as Anthraquinone or Arasan prior to field planting. Arasan 42-S is more widely used because it is easier to handle, and protects seeds from birds and some rodents (Muford 1984). In order to bind repellent to the seed, an adhesive such as Dow Latex 512R or Dow Methocel is used, the later being commonly used with Anthraquinone repellent (Mugford 1984). In Tennessee, 85 percent of the seed treated with thiram-endrin mixture repellent germinated and only 32 percent of the seed not treated germinated in the field (Mignery and Yeatman 1960). The repellent and stratification treatments each increase the weight of seed by about 10 percent and 25 percent (Williston and Balmer 1983). Repellents may reduce germination, but direct seeding is rarely successful without them (Derr and Mann 1971).

SEEDING METHODS AND SOWING RATES

A wide array of direct seeding methods exists for shortleaf pine. Seed may be sown in spots or rows, or broadcast mechanically or by hand. It can also be sown aerially using a helicopter or fixed-wing aircraft. Broadcast seeding by hand or using a hand-operated broadcast seeder is the easiest and most economical method to use when small areas are seeded. About 12.5 acres per day can be seeded using a cyclone seeder on relatively level sites (Campbell 1982). Sites accessible by vehicles may easily be seeded using mechanical broadcast seeders, allowing rapid seeding of sites. Spot seeding or row seeding methods use less seed and provide better coverage. Conserving seed is important when seed is scarce or high priced.

Spot seeding or row seeding ensures better germination, more uniform spacing and facilitates future mechanical harvesting. These two methods are, however, slower and more labor intensive than broadcast methods. Spot seeding or row seeding may appeal to private landowners with small tracts of land. In the Missouri Ozarks, Liming (1945) recommended spot sowing because it was an efficient use of seed compared to broadcast seeding. For inaccessible areas, aerial seeding is the most practical method. It is often most efficient to seed blocks of 500 acres or more by helicopter or fixed-wing aircraft (Derr and Mann 1971).

Optimum seeding rates are dependent on seedbed conditions, seed quality, timing of sowing, seeding method and desired stocking. Recommended sowing rate for winter sowing is 2 lb/acre of unstratified seed on unburned seedbed if the goal is 1000 seedlings/acre at end of first year (Krugman and Jenkins 1974), and 0.55 lb on burned sites (Boggs and Wittwer 1993). The recommended sowing rate in Missouri is 0.5 lb/acre on bulldozed sites, a rate similar to that recommended by Boggs and Wittwer (1993). According to Yocom and Lawson (1977) about 100 seeds are required to establish one seedling in Arkansas, but this number varies on site preparation and environmental factors. This agrees with Haney's (1962) estimate that 100,000 sound seeds per acre are required to adequately stock shortleaf pine on disturbed sites in the Piedmont of North Carolina. For spot seeding three to eight seeds are sown per spot, while for row sowing single seeds are sown a foot apart along a line. Other recommended rates are listed in Table 1, and these are based on the assumption that there are 48,000 seeds per pound (Campbell 1982). These rates are similar to those recommended by Derr and Mann (1971). Wherever practical, seeds should be pressed lightly into the soil surface or seed covered lightly with soil for better germination (Campbell 1982).

TIMING OF SOWING

Table 1. Recommended sowing rates for shortleaf pine, assuming 100% sound, stratified and repellent coated seeds (adapted from Campbell 1982)

Sowing method	Seeding rate per acre	
	No. of seed	Pounds
Broadcast	20,000	0.48
Rows 10’ apart, 1’ between rows	4,350	0.10
Spots spaced 6’ x 10’, 8 seeds/spot	5,800	0.14

Stratified, repellent-coated seed should be sown in late winter or early spring. When seed is sown in February or March, seed germination will begin in early April as temperature and moisture conditions become favorable. Unstratified seed should be sown in fall so the seeds are naturally stratified during winter. In the Missouri Ozarks, unstratified shortleaf pine seed germinated better when it was sown in December compared to seed sown in February or March (Phares and Liming 1961). In Oklahoma, sowing unstratified seed in January resulted in a greater number of seedlings established than a March sowing of stratified seed (Figure 2, Boggs and Wittwer 1993). On some sites, fall sowing may result in high predation of seed due to deterioration of the repellant coating.

SEEDLING ESTABLISHMENT AND GROWTH

The first growing season is the most critical for establishment and survival of newly established shortleaf pine (Phares and Liming 1961). Mortality after the first year is usually low (Derr and Mann 1971). Establishment and survival during the first year depends on adequate moisture during germination and seedling establishment, freedom from competition, soil type and protection from predation. Summer droughts can reduce survival to 20 percent in the first growing season. Because of these factors, it is important to determine the success of the regeneration after direct seeding, particularly in the first year.

It is recommended that at least two seedling inventories be conducted during the first year: one during summer when germination is completed and the other at the end of the first growing season when danger of mortality from drought is past. The difference between the two inventories indicates losses during the first summer (Derr and Mann 1971). Seeding success can be judged by number of seedlings per acre and their distribution. When the number of seedlings is between 1,500 and 3,500 per acre, the usual range of stocking is between 60 and 80 percent. The minimum acceptable stocking is 55 percent (Williston and Balmer 1983). On the Mark Twain National Forest in Missouri, an acceptable stocking is 435 seedlings per acre at age five (Henken and Peterson 1984).

Inventory methods for evaluating seeding success depend on the sowing method. For broadcast seeding a minimum of 25 circular mil-acre plots per acre should be checked for number of germinated seeds or established seedlings. This number is then converted to per-acre basis. Row and spot seeding are inventoried by examining segments of rows or spots with established seedlings and converting to per-acre basis (Derr and Mann 1971). For optimum growth some pre-commercial thinning may be necessary in overstocked stands.

Soil texture affects shortleaf pine seed mortality and root development (Table 2, Pomeroy 1949). There were no significant differences in germination percentages between soil types, but significantly greater mortality and reduced root development were encountered on clayey soils.

Table 2. Effect of soil texture on germination, mortality and root depth (adapted from Pomeroy 1949)

Soil texture	Germination (%)	Mortality (%)	Root depth (inches)
Sand	79	32	1.39
Loam	73	31	1.26
Clay Loam	85	47	0.85

The literature reveals that growth of direct seeded shortleaf pine can be higher (Phares and Liming 1960), the same (Farrar 1959, Harrington et al. 1986) or lower (Williston and Balmer 1983) than planted shortleaf pine. Most observations are based on young seedlings and these observations may differ from older ones. Observations on a 14-year-old experiment in Missouri indicate that direct seeded shortleaf pine had better survival and higher growth rate than planted shortleaf pine (Phares and Liming 1960). In loblolly pine, early growth was slower with direct seeding, but at rotation age (20 years) the total volumes of planted and direct seeded trees did not differ significantly (Campbell 1985). Although growth results for direct seeding and planting are inconsistent, there is no question that direct seeding is a viable alternative to planting.

RESEARCH AND INFORMATION GAPS

Given the limitations of using herbicides on some public land, alternative methods for managing hardwood competition need to be identified. Cost-benefit analysis of the various planting options (e.g. direct seeding, bareroot and containerized seedlings) has not been done. This information, when made available, will offer landowners the possibility of making better-informed decisions on artificial regeneration of shortleaf pine.

Little is known about the genetics of shortleaf pine in Missouri. Survival and growth is likely to depend on the seed source. Seed source studies will provide guidance on where the best seed should be collected for sowing at a particular site.

Most of the studies in Missouri were carried out from the 1940s to 1960s with limited statistical designs. Up-to-date information is required to supplement or confirm historical research studies. New studies could include use of fertilizer to hasten early seedling growth. Also, the optimum time of sowing is not clear. Ripping to improve water penetration and to break up hard layers on some sites could be examined, and information is needed on the stocking rates of pine and pine-oak woodlands in Missouri.

Despite the potential benefits of direct seeding, this regeneration method is not being widely used in Missouri. Direct seeding was a common regeneration method in Missouri from the 1960s to the 1980s, but fell out of favor with many public agencies because the availability of seed was limited. The only seed available was genetically improved seed, and direct seeding did not efficiently use this expensive and limited seed. Also, there was a perception by some resource managers that planting seedlings offers more benefits. However, direct seeding continues to be used by small private landowners because it is perceived to be low-cost regeneration method.

Specifically targeted seed collections of natural shortleaf pine could be made in order to make seed available for direct seeding. Given the large acreages with the potential to be restored to shortleaf pine, direct seeding is likely to be a viable method to make a short-term impact on the restoration efforts on both public and private lands in Missouri.

CONCLUSION

Direct seeding is potentially a simple, fast, economical and flexible method that can supplement natural shortleaf pine reproduction or reintroduce shortleaf pine on sites where it once grew. If the benefits outweigh the disadvantages, and seed is available, direct seeding has the potential to make a significant contribution to shortleaf restoration efforts in Missouri. Obtaining successful establishment and growth of directly seeded plants bears certain risks. However, these risks can be reduced by understanding factors that make direct seeding work. Reviewing past experiences with direct seeding of shortleaf pine illustrates that successful direct seeding depends on:

1) good site preparation,
2) high quality seed,
3) proper timing of sowing,
4) protection of seed from birds and rodents,
5) good moisture during germination and establishment,
6) sufficient light, and
7) reduced competition.

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